

# Ballistic Research Laboratories

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BALLISTIC LABORATORY



## REPORT

### REPORT ON INVESTIGATION OF THE CAUSES UNDERLYING ERRATIC POWDER PRESSURES OBTAINED FROM CRUSHER GAUGES

(IN CONNECTION WITH PROJECT RB 116)  
(O.O. 413.6/12432 - APG 413.6/487 )

BY

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ABERDEEN PROVING GROUND  
ABERDEEN, MD.

TKV/cvp  
ABERDEEN PROVING GROUND, MD.,  
FEBRUARY 18, 1936.

REPORT ON INVESTIGATION OF THE CAUSES UNDERLYING ERRATIC  
POWDER PRESSURES OBTAINED FROM CRUSHER GAUGES

{IN CONNECTION WITH PROJECT RB 116)  
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OBJECT OF TEST

To obtain comparative data regarding the behavior of crusher gauges, assembled under different conditions and with different tolerances, from controlled firings in the 3" A.A. Gun Liner M3, No. 138, chromium plated.

DISCUSSION

OCM Item 12462 directed certain tests to be performed on 3" A.A. Gun Liner M3, #138, which was chromium plated in the bore at the Naval Gun Factory, Washington Navy Yard. This test provided for proof firing to be followed by 50 rounds in 5-round series, with taking of periodic bore measurements and bore impressions. The results of this test, insofar as effect on the liner is concerned, are reported in Firing Record 8807, (O.P. 4987; O.O. 472.93/4449; A.P.G. 472.91/362), and in First Partial Report on test of 3" A.A. Gun Liner M3, No. 138, chromium plated, and Fifth Report on O.P. No. 4987, Ordnance Program 4987, OCM Item 12462, dated February 12, 1936.

The Proving Ground has experienced erratic results in powder pressure readings obtained from crusher gauges for some time. Prior to the adoption of the new standard firing record forms, which provide for recording individual pressures obtained as well as mean pressures, these erratic results were not so apparent. The old firing record forms reported the mean pressures only, and wide variance in individual readings were often

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absorbed in the mean result. In cases where standard firings were made under these conditions of pressure taking or where established charge-pressure curves for a lot of powder were used to obtain data for firings, and the firings made from the curves gave contrary results, the effects of erratic individual pressures were forcefully brought to view.

The cannon crusher gauges in use today are of the Noble type, an outgrowth of the Rodman knife gauge. Those used at the Aberdeen Proving Ground have been in service for many years, many having been formerly used at Sandy Hook Proving Ground. The specifications for these gauges provide for pistons to be made of hardened tool steel, ground to size and the gauge bodies to be made of forged No. 3 steel. This latter steel corresponds to W.D. 1055, a medium carbon steel. In the absence of specified physical requirements and heat treatment of the bodies and pistons, it can be seen that there should be great variance in their ability to withstand scoring, distortion and permanent deformation. The clearance between the piston and the body is 0.0002" with tolerances of +.004" in cylinder diameter, and -.0004" in piston diameter.

The regulations at the Proving Ground provide for the selection of cannon pressure gauges for standardization firings having clearances of .0002" between piston and cylinder with tolerances of +.0002" on the cylinder diameter and -.0002" on the piston diameter. For other than standardization firings the clearance is .0002" between piston and cylinder, with tolerances of +.0004" on cylinder diameter and -.0004" on piston diameter.

Mr. R. H. Kent in a paper entitled "Report on Some Sources of Error in Piezo-electric and Crusher Gauge Measurements (In Connection with Project RB 117)", dated Aberdeen Proving Ground, Dec. 2, 1935, concludes that the pinching effect observed in the case of the piezo-electric gauges should also affect the measurements made with the copper crusher gauges. This pinching effect is caused by the pressure of the powder gases applied to the exterior cylindrical surface of the gauge body, distorting the inner cylinder wall and binding the piston, so as to prohibit free movement.

From all of the foregoing it was concluded that the firings to be conducted in the 3" A.A. Gun Liner M3, No. 138, presented an excellent opportunity to schedule some tests of crusher gauges in which their behavior under certain variables of assembly and selection could be observed.

In O.O. 471.91/2052; A.P.G. 472.91/362-2, the Ordnance Office authorized tests to be conducted in this gun along the following lines:

(a) Select 16 medium caliber crusher gauges which are in good condition, assemble pistons to 8 of these gauges to give total clearance in each case of .0005" between cylinder wall and piston. Assemble pistons to the other 8 crusher gauges to give a total clearance of .0010" between cylinder wall and piston.

(b) Assemble all gauges with the cylinder wall and piston wiped dry, no lubricant to be used about the gauges except on closing cap threads and body washer.

(c) All gauges to be assembled, disassembled, measured, etc., by the Gauge Section, using the same procedure at all times.

(d) Copper cylinders to be of the same lot and anneal with zero initial compression.

(e) Four gauges of each lot of 8 described in (a) above, to be assembled with standard copper obturator cups, the remaining gauges to have the copper cup replaced with a wax seal consisting of 2 parts cup grease, 2 parts beeswax and 1 part resin.

(f) The 16 gauges will be divided into four sets of four gauges each, each set to consist of:

1 gauge - .0005" clearance; copper cup  
1 gauge - .0005" clearance; wax obturator  
1 gauge - .0010" clearance; copper cup  
1 gauge - .0010" clearance; wax obturator

These gauges are all numbered and sets will remain intact throughout the whole test.

(g) Forty rounds to be fired at five different pressures:

8 at 20,000 lbs. per sq. in.
8 at 27,000 "
8 at 31,500 "
8 at 36,000 "
8 at 41,200 "

(h) Each round to have a set of four gauges, assembled as described in (f) above, inserted in the case.

(i) In half of the rounds at each pressure, the set of gauges is to be fixed in the bottom of the case. In the other half of the rounds, the gauges are to be placed in the case in accordance with current procedure at the Proving Ground.

### Procedure

A lot of powder was selected from that available at the Proving Ground for use in this test. The powder selected was DuPont 1492 - 1918 - for 6" Gun M1900-03-05. It is a pyro powder, multiperforated grain having a web thickness of 0.0360". This powder is suitable for use in the 3" A.A. Gun M3.

Standard 3" cast iron proof slugs, weighing 15 lbs. each, were used in all firings. Cartridge cases, 3" A.A. Mk. II Al, drawing 71-5-3, unmodified, were used with M21 Primers, Lot 1355-15, in all rounds.

Firings were conducted in groups of five rounds each, the first round of each group being a warming round, the remaining four having gauges assembled as prescribed. This was necessary due to the limited number of gauges used, 16 in all or sufficient for 4 rounds, and the requirements of the original directive (OCM Item 12462) which called for five-round groups between stargauging, etc. Two groups were fired at each pressure, each group being fired on a different day usually since the gauges had to be disassembled and reassembled by the Gauge Section between groups and the necessary stargauging of the liner performed. Boulenge muzzle velocities were taken on all rounds.

The description of assembly of each group of five rounds follows:

<u>Round</u>	<u>Fixed or Loose in Case</u>	<u>Gauge No.</u>	<u>Piston Clearance</u>	<u>Obturator Seal</u>
Warming	-	No gauges	-	
1	Fixed	5942	.0010	Wax
		4525	.0010	Copper
		4734	.0005	Wax
		4190	.0005	Copper
2	Fixed	4970	.0010	Wax
		2422	.0010	Copper
		4748	.0005	Wax
		2834	.0005	Copper
3	Loose	5908	.0010	Wax
		3640	.0010	Copper
		4744	.0005	Wax
		4329	.0005	Copper
4	Loose	4774	.0010	Wax
		1728	.0010	Copper
		4875	.0005	Wax
		3259	.0005	Copper

The problem of fixing the four gauges in rounds 1 and 2 of each series presented difficulties. Various metal holders were devised and tried out in an effort to hold the four gauges upright in the case and against the case wall in order that there would be no interference with the action of the primer. The MII Al case is rather long, and the mouth opening is only 3" in diameter. With the facilities available at the Proving Ground there appeared to be no simple and inexpensive method of accomplishing this. The Research Division at the Proving Ground suggested that the four gauges be held together with strong rubber bands, each gauge in contact with the primer body and resting on the bottom of the inside of the case. It was believed that no interference with the primer action would occur. A simple fixture was devised for assembling the gauges in position in this manner, and this method was used for fixing the gauges in rounds 1 and 2 of each series.

The data obtained in the firings are shown on the attached sheets, Exhibits "A" to "F". The data shown on Exhibit "F" was obtained by firing 2 additional groups using a powder charge to give pressures lower than those used for the initial test shown on Exhibit "A". This was done to obtain additional data in the lower pressure range and to see if the high pressures shown on Exhibit "E" had permanently affected the gauges.

Pressures obtained were not corrected in any way for erosion, etc.

#### Analysis of Data

##### Exhibit "A"

It will be noted that the results obtained in the firings of the first series, Rounds 14, 15, 16 and 17, showed very little difference between gauges with different characteristics. When these firings were repeated three days later (Rounds 19, 20, 21 and 22) under as near identical conditions as possible, it is noted that the gauges having pistons with .0005" clearance and wax obturators in Rounds 19, 20 and 22, showed considerable dispersion from the other gauges assembled with them in the rounds.

The dispersions from the mean values for all combinations of variables as shown in columns 13 to 16, inclusive, indicate that the gauges having large piston clearance (.0010") and assembled with copper cup obturators show very much less dispersion in pressure than any other combination tested.

Attention is invited to gauge No. 4744 assembled in the 3rd round of each series. This gauge has a piston with

.0005" clearance and was always assembled with a wax obturator. Its behavior, however, is unlike that of other gauges with similar characteristics, and the results obtained from it are more like those obtained with the .0010" clearance gauges. This gauge was carefully checked and rechecked several times to find out the cause for this paradoxical behavior. No explanation is offered.

Exhibit "B"

The results shown for these series continue to follow the trend indicated in Exhibit "A". The mean dispersions are of greater magnitude due to the greater effect of the low reading gauges. The dispersion in columns 11 and 12 indicate that fixing the gauges in the round is not an advantage, but contributes to greater deviations.

Gauge No. 4744 continues to behave at variance with similar gauges. Gauges having large piston clearance and copper obturator cups have the least dispersion.

Exhibit "C"

The results of previous firings are unchanged by these series. Through a misunderstanding one gauge in each series, Rounds 35 and 42 were assembled with copper cups instead of wax. This change was considered in arriving at the mean values.

Exhibits "D" and "E"

The results of these firings are consistent with previous results.

Exhibit "F"

These series were fired to see what effect, if any, the repeated firings had on the gauges.

It was expected that the results would be consistent with those shown on Exhibit "A". Such was not the case, and it appears that some of the gauges have been permanently deformed, or otherwise changed so that they no longer behave normally.

CONCLUSIONS

From the data obtained in these tests it appears that gauges with tight pistons will give consistently lower pressures and greater dispersions than will be given by gauges having pistons with greater clearance.

That these tests do not give sufficient data on which to base the limits of clearance between pistons and cylinders in gauges.

That definite conclusions cannot be drawn from this data regarding the effects of fixation of gauges, or use of wax compounds in lieu of copper obturator cups; due to the confusing effects of the variables introduced into the tests.

RECOMMENDATIONS

That further tests be made to determine the maximum piston clearance which can be allowed.

That no further tests be made at this time having reference to fixation of gauges in the round.

That further investigation of lubrication of the gauge parts be conducted.

That the search for a substitute for copper obturating cups be continued.

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RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" A.A. GUN, M3, WITH CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES (MED CAL); 4 PER ROUND, ALL ASSEMBLING, MEASURING ETC BY GAUGE SECTION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/sq.in. #/ <sup>1</sup> /30 in.	MEDIUM CALIBER GAUGE NO.	PRESSURE #/ <sup>1</sup> SQ. IN. (0.015" MIC spindle)	MEAN OF GAUGES WITH 0.0005"	MEAN OF GAUGES WITH 0.0010"	MEAN OF GAUGES WITH COPPER OBT. CUPS	MEAN OF GAUGES WITH WAX OBTRUATOR	MEAN OF GAUGES ASSEMBLED TO ROUND	INDIV MEAN PRESSURE	MAX DISPERSION GAUGES FIXED IN ROUND	MAX DISPERSION GAUGES LOOSE IN ROUND	INDIV DISPERSION PISTON CLEARANCE	INDIV DISPERSION PISTON CLEARANCE	INDIV DISPERSION COPPER OBT. CUPS	INDIV DISPERSION WAX OBT	FIRING DATE	REMARKS
2	14	20,000	5942 4525 <sup>38202</sup> 4734 4190	19,550 19,000 18,450 19,300	19,275 19,150 19,125	19,250	19,250	19,200	+350 -200 -250 +100	600	+275 -275 -175 +175	+300 -180 -300 +150	+300 -175 -225 +375	+300 -175 -225 +375	+300 -175 -225 +375	10-148	Very consistent
3																	
4																	
5																	
6	15	Pyro powder	4970 2422 4748 2834	18,900 19,100 19,050 18,650	19,000 19,075 18,850	18,975	18,975	18,925	-25 +175 +125 -275	450	-150 +100 -200 +200	-150 +160 -200 +225	-150 +160 -200 +225	-150 +160 -200 +225	-150 +160 -200 +225	10-148	Very consistent
7																	
8																	
9																	
10	16		5908 3640 4744 4329	19,550 19,650 19,200 19,100	19,600 19,075 19,150	19,575	19,575	19,525	+175 +225 -175 -275	550	-50 +20 -80 -80	+175 +225 -175 -275	+175 +225 -175 -275	+175 +225 -175 -275	+175 +225 -175 -275	10-148	Very consistent
11																	
12																	
13																	
14	17		4774 1728 4875 3259	19,240 19,500 19,150 20,150	19,270 19,275 19,650	19,195	19,510	-270 -10 -360 +640	1000	+120 -120 -325 +500	+120 -120 -325 +500	+120 -120 -325 +500	+120 -120 -325 +500	+120 -120 -325 +500	10-148	Very consistent	
15																	
16																	
17																	
18	19	20,000	5942 4525 4734 4190	18,975 19,100 15,150 19,400	19,040 19,275 17,275	19,150	18,150	18,150	+825 +450 -3000 +1250	4,250	-60 +60	-60 +60	-60 +60	-60 +60	+1910		
19																	
20	20		4970 2422 4748 2834	19,000 19,000 13,500 18,350	19,000 18,675 15,925	18,675	17,460	+1540 +1540 -3960 +890	5,500	0 0	+325 +325	0 0	+325 +325	+1780	10-148	TIGHT PISTON - WAX - low pressure	
21																	
22	21		5908 3640 4744 4329	19,400 19,200 17,450 19,250	19,200 19,200 18,350	18,425	18,825	+575 +375 -1375 +425	1950	+150 -100 -300 +30	+150 -100 -300 +30	+150 -100 -300 +30	+150 -100 -300 +30	+4950	10-148	TIGHT PISTON, WAX - low pressure	
23																	
24																	
25																	
26	22		4774 1728 4875 3259	19,025 19,150 12,800 19,750	19,090 19,275 16,275	19,050	17,680	+1245 +1470 -1880 +2070	6950	-65 +65	-65 +65	-65 +65	-65 +65	+3,915 +3,915	10-148	TIGHT PISTON, WAX - low pressure	
27																	
28																	
29																	
30	23																
31																	
32																	
33																	
34	MEAN VALUES	20,000	18,640	18,675	18,210	18,230	18,660	18,640	—	2,700	2,610	2,460	197	445	2,340		
35																	

EXHIBIT "A"

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" X 4" GUN, MB CHROMIUM PLATED LINER #128

SELECTED PRESSURE GAUGES (LINE D.CAL.), + PERIODICALLY ASSEMBLING MEASURING ETC BY GAUGE SECTIONS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SERIAL NUMBER OF ROUND	EXPECTED PRESSURE GAUGE NO.	MEDIUM CALIBER PISTON CL	PRESSURE GAUGES #1 SIGHT PISTON CL	MEAN OF GAUGES WITH 0.0005" PISTON CL	MEAN OF GAUGES WITH 0.0010" PISTON CL	MEAN OF GAUGES WITH COPPER WAX OBTRUKTOR	MEAN OF GAUGES ASSEMBLED TO ROUND	INDIV MEAN PRESSURE GAUGES FIXED IN ROUND	MAX. DISPERSION GAUGES LOOSE IN PISTON ROUND	INDIV DISPERSION WITH 0.0005" PISTON CLEARANCE	INDIV DISPERSION WITH 0.0010" PISTON CLEARANCE	INDIV DISPERSION COPPER OBTRUKTOR	INDIV DISPERSION COPPER OBTRUKTOR	INDIV DISPERSION VVAK OBTRUKTOR	FIRING DATE	REMARKS	
2	24	27,000	5942	-26,400	{ 25,790	{ 25,815	{ 25,750	+2,620	4,350	+ 610	+ 4,650	+ 610	+ 4,650	+ 610	+ 4,650	↑	
3		4525	-25,175					+1,395		- 610	- 640						
4		{ 4734	-17,100	{ 21,775				-6,680		- 4,675							
5		{ 4190	-26,450					+2,670		+ 4,675	+ 640						
6	25	PYRO POWDER	4970	-25,050	{ 25,800	{ 25,450	{ 18,875	+2,885	13,850	- 750	+ 610	+ 610	+ 610	+ 610	+ 610		
7			2422	-26,550				+4,385		+ 750	+ 1100						
8			4748	-12,700	{ 18,525			-9,465		- 5,825							
9			2834	-24,350				+2,185		+ 5,825	- 1100						
10	26		5908	-26,000	{ 25,075			+2,710	5,300	+ 925	+ 2,650	+ 925	+ 925	+ 925	+ 925	Σ	
11			3640	-24,150				+ 860		- 2,650							
12			4744	-20,700	{ 21,500	{ 23,225		- 2,540		- 800							
13			4329	-22,300				- 910		+ 800							
14	27		4774	-25,750	{ 26,300			+4,210	14,400	- 850	+ 6,650	- 850	+ 6,650	+ 6,650	+ 6,650		
15			1728	-26,850				+5,310		+ 550	+ 2,875	+ 550	+ 2,875	+ 2,875	+ 2,875		
16			4875	-12,450	{ 16,775	{ 23,975		-9,090		- 4,325							
17			3259	-21,100				- 490		+ 4,325	- 2,875	- 2,875	- 2,875	- 2,875	- 2,875		
18	28	27,000	5942	-26,000	{ 25,650			+19,60	7,950	+ 350	+ 3,775	- 350	+ 3,775	+ 3,775	+ 3,775		
19			4525	-25,300				+1,360		- 550	- 550	- 550	- 550	- 550	- 550		
20			4734	-18,450	{ 22,425	{ 25,850	{ 22,225	+1,360		- 3,975							
21			4190	-26,400				+2,540		+ 2,975	+ 550	+ 550	+ 550	+ 550	+ 550		
22	30		4970	-25,700	{ 25,850	{ 21,650	{ 21,650	+2,140	8,400	- 150	+ 4,050	+ 150	+ 4,050	+ 4,050	+ 4,050		
23			2422	-26,000				+2,440		+ 150	+ 525	+ 150	+ 525	+ 525	+ 525		
24			4748	-17,600	{ 21,275	{ 25,475	{ 25,475	-5,960		- 3,675	- 4,050	- 3,675	- 4,050	- 4,050	- 4,050		
25			2834	-24,950				+3,300		+ 3,675	- 525	- 525	- 525	- 525	- 525		
26	31		5908	-26,500	{ 27,175			-540	1,350	- 675	- 50	- 675	- 50	- 50	- 50	Σ	
27			3640	-27,850				+ 810		+ 675	+ 325	+ 675	+ 325	+ 325	+ 325		
28			4744	-26,600	{ 26,900	{ 27,525		-440		- 800	+ 50	- 800	+ 50	+ 50	+ 50		
29			4329	-27,200				+1,160		+ 300	- 325	+ 300	- 325	- 325	- 325		
30	32		4774	-25,150	{ 25,425			+1,350	7,700	- 275	+ 3,375	+ 275	+ 3,375	+ 3,375	+ 3,375		
31			1728	-25,700				+1,840		+ 275	- 200	+ 275	- 200	- 200	- 200		
32			4875	-18,400	{ 22,250	{ 25,900	{ 21,775	+2,340		- 3,850	- 3,375	- 3,850	- 3,375	- 3,375	- 3,375		
33			3259	-26,100				+3,140		+ 3,850	+ 200	+ 3,850	+ 200	+ 200	+ 200		
34	MEAN		VALUES	27,000	23,660	21,430	25,880	25,400	21,900	23,660	9,890	7,190	3,430	535	890	3,920	
35																	

EXHIBIT

EXHIBIT "B"

**RECAPITULATION PRESSURE DATA - SPECIAL GAUGES IN SURVEYING CHROMIUM PLATED LIQUID THERMOMETER**

SELECTED PRESSURE GAUGES (INCHES) AS PER REQUEST FOR RECORDING MEASUREMENTS OF VARIOUS STATIONS

\* NOT CONSIDERED IN AVERAGES IN HNES '34-35  
\* MEAN OF 6 VALUES ONLY

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" A.A. SHELLS CHROMIUM PLATED LINER #138  
 SELECTED PRESSURE GAUGES (MEDICAL); OF PER ROUND; ALL ASSEMBLING MEASURING ETC BY GAUGE SET NO.

1 SERIAL NUMBER OF ROUND	2 EXPECTED PRESSURE #/SQ.IN	3 MEDIUM CALIBER GAUGE NO.	4 PRESSURE #/SQ.IN (075" MICK SPINDLE)	5 MEAN OF GAUGES WITH PISTON CL. PISTON CL. OBTCUPS OBTURATOR	6 0.0005" COPPER WAX PISTON CL. OBTCUPS OBTURATOR	7 0.0010" COPPER WAX PISTON CL. OBTCUPS OBTURATOR	8 ALL GAUGES IN ROUND	9 INDIV DISPERSION GAUGES IN PRESSURE FIXED	10 MAX DISPERSION GAUGES LOOSE	11 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	12 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	13 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	14 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	15 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	16 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	17 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	18 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	19 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	20 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	21 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	22 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	23 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	24 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	25 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	26 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	27 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	28 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	29 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	30 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	31 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	32 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	33 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	34 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	35 MAX DISPERSION GAUGES PISTON CL. OBTCUPS	DATE OF FIRING	REMARKS
2 49	36,000	5942	34,000	{ 33,975 }	{ 0.0005" COPPER WAX PISTON CL. OBTCUPS OBTURATOR }	{ 36,460 }	{ 27,400 }	31,930	+2,070 18,175	-9,185	+9,185	+2,25	+6,600																							
3		4525	-33,950						+2,020	-11,130	-11,130	-2,25	-2,515																							
4		4734	-20,800	{ 29,840 }					+7,045	+2,430 16,525	+2,430 16,525	+2,430 16,525	+2,430 16,525	+2,430 16,525																						
5		4190	-38,975						+5,180	-11,245	-11,245	-11,245	-11,245	-11,245																						
6 50	6,400	4970	34,300	{ 35,675 }					+1,625	+2,475	+2,475	+2,475	+2,475	+2,475																						
7		2422	-37,050						-2,700	-14,750	-14,750	-14,750	-14,750	-14,750																						
8		4748	-20,525	{ 28,060 }					+2,475	-14,750	-14,750	-14,750	-14,750	-14,750																						
9		2834	/35,600						+10,015	-10,015	-10,015	-10,015	-10,015	-10,015																						
10 51		5908	-34,675	{ 36,390 }					+1,800	+2,585	+2,585	+2,585	+2,585	+2,585																						
11		3640	-38,100						-3,200	-2,700	-2,700	-2,700	-2,700	-2,700																						
12		4744	-33,600	{ 36,190 }					+2,475	-14,750	-14,750	-14,750	-14,750	-14,750																						
13		4329	-38,775						+2,475	-14,750	-14,750	-14,750	-14,750	-14,750																						
14 52		4774	-29,450	{ 33,400 }					-250	22,400	22,400	22,400	22,400	22,400																						
15		1728	-37,350						+7,650	-10,015	-10,015	-10,015	-10,015	-10,015																						
16		4875	-14,950	{ 26,460 }					+14,750	-10,015	-10,015	-10,015	-10,015	-10,015																						
17		3259	-36,975						+7,275	+10,015	+10,015	+10,015	+10,015	+10,015																						
18 54	36,000	5942	-39,550	{ 40,350 }					+30,500	20,100	20,100	20,100	20,100	20,100																						
19		4525	-41,150						+4,650	-13,900	-13,900	-13,900	-13,900	-13,900																						
20		4734	-22,600	{ 32,650 }					+6,200	+10,050	+10,050	+10,050	+10,050	+10,050																						
21		4190	-42,700						+3,800	-7,400	-7,400	-7,400	-7,400	-7,400																						
22 55		4970	-38,100	{ 38,600 }					+4,800	+1,300	+1,300	+1,300	+1,300	+1,300																						
23		2422	-39,100						-11,700	-8,825	-8,825	-8,825	-8,825	-8,825																						
24		4748	-22,600	{ 30,000 }					+3,100	-8,825	-8,825	-8,825	-8,825	-8,825																						
25		2834	-37,400						+1,650	-7,400	-7,400	-7,400	-7,400	-7,400																						
26 56		5908	-40,800	{ 39,470 }					-1,025	-5,500	-5,500	-5,500	-5,500	-5,500																						
27		3640	-38,125						-5,500	-250	-250	-250	-250	-250																						
28		4744	-38,600	{ 38,850 }					-50	+250	+250	+250	+250	+250																						
29		4329	-39,100						+1,650	+4,850	+4,850	+4,850	+4,850	+4,850																						
30 57		4774	-30,900	{ 34,850 }					+925	17,800	17,800	17,800	17,800	17,800																						
31		1728	-38,800						+8,825	-4,100	-4,100	-4,100	-4,100	-4,100																						
32		4875	-21,000	{ 25,100 }					-8,975	+4,100	+4,100	+4,100	+4,100	+4,100																						
33		3259	-29,200						-775	-4,400	-4,400	-4,400	-4,400	-4,400																						
34																																				
35	36,000		33700	30,960	36,600	37,645	29,800	33,745	17,825	12,000	6,400	1700	1285	5450																						

EXHIBIT "D"

RECAPITULATION - PRESSURE DATA - SPECIAL GAUGES IN 3" A A GUN, M 3 - CHROMIUM PLATED LINER #138  
SELECTED PRESSURE GAUGES - (MED. CAL); 4 per round. All assembling, measuring etc by GAUGE SECTIONS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SERIAL NUMBER OF ROUND	EXPECTED PRESSURE #/SQ-IN.	MEDIUM CALIBER GAUGE NO. (0.75 MICR SPINDLE)	PRESSURE #/SQ-IN.	MEAN OF GAUGES WITH PISTON CL	COPPER WAX GAUGES IN PISTON CL	MEAN OF ALL GAUGES IN OBSTACLES OUTWARD	MAX DISPERSION GAUGES FIXED ROUND	INDEX MAX DISPERSION GAUGES	MAX DISPERSION GAUGES	INDIVIDUAL DISPERSIONS WITH PISTON CL	DATE OF FIRING	REMARKS					
2	59	41,200	5942 / 38100	{ 40,400 }	{ 32,670 }	{ 37,810 }	+ 290	15.985	- 2,300	+ 5430							
3		4525 / 42700		{ 42,950 }			+ 4,890		+ 2,300	- 250							
4	(4#1308)	4734 / 27225	35215				- 19,595		- 7,990		- 5,430						
5	X1192	4190 / 43200	34,050				+ 5,310		+ 1,000	+ 250							
6	60	POWDER (PYRO)	4970 / 42600	{ 42,775 }	{ 34,500 }	{ 38,415 }	+ 4,185	16.850	- 175	+ 8,100							
7		2422 / 42950		{ 42,475 }			+ 4,535		+ 175	+ 475							
8		4748 / 26100	34,050				- 12,315		- 7,950	- 8,100							
9		2834 / 42000					+ 3,585		+ 1,950	- 475							
10	61	5908 / 41050		{ 41,025 }	{ 40,850 }	{ 41,150 }	- 100	1250	+ 25	+ 200							
11		3640 / 41000		{ 41,450 }			- 150		- 25	- 450							
12		4744 / 40650	41.125				- 300		- 775	- 200							
13		4329 / 41900					+ 750		+ 775	+ 450							
14	62	4774 / 33050		{ 38,200 }	{ 30,275 }	{ 36,340 }	- 3,290	15.850	- 5,150	+ 2,175							
15		1728 / 43350		{ 42,400 }			+ 7,010		+ 5,150	+ 950							
16		4875 / 27500	34,475				- 8,870		- 6,925	- 2,775							
17		3259 / 41450					+ 5,810		+ 6,925	- 950							
18	64	5942 / 39,200		{ 41,300 }	{ 30,480 }	{ 35,460 }	+ 3,850	21700	- 2,100	+ 8,750							
19		4525 / 43,400		{ 40,450 }			+ 7,950		+ 2,100	+ 2,950							
20		4734 / 21,700	29,600				- 13,750		- 7,900	- 8,750							
21		4190 / 37,500					+ 2,050		+ 7,100	- 2,950							
22	65	4970 / 42,350		{ 41,600 }	{ 32,700 }	{ 34,275 }	+ 8,075	19,300	+ 750	+ 9,650							
23		2422 / 40,850		{ 35,850 }			+ 6,675		- 750	+ 5000							
24		4748 / 23,050	26,950				- 11,225		- 3,900	- 9,650							
25		2834 / 30,850					- 3,425		+ 3,900	- 5,000							
26	66	5908 / 42,950		{ 43,600 }	{ 41,515 }	{ 42,200 }	+ 750	4,175	- 650	+ 1,435							
27		3640 / 44,250		{ 42,815 }			+ 1,050		+ 650	+ 1,375							
28		4744 / 40,075	40,075				- 2,125		- 710	- 1,435							
29		4329 / 41,500					- 700		+ 710	- 1,375							
30	67	4774 / 32,500		{ 33,325 }	{ 28,900 }	{ 32,290 }	+ 210	11,900	- 825	+ 3,600							
31		1728 / 34,150		{ 35,675 }			+ 1,860		+ 825	- 1,525							
32		4875 / 25,300	31,250				- 6,990		- 5,950	- 3,600							
33		3259 / 37,200					+ 4,910		+ 5,950	+ 1,525							
34		37,240	34,180	40,550	40,510	34,000	37,240	18,400	3,300	5260	1498	1622	4993				
35																	

EXHIBIT F

EXHIBIT "E"

RECAPITULATION - PRESSURE DATA 2" AA GUNS CHROMIUM PLATED LINER #138

SELECTED PRESSURE GAUGES (MEDICAL) + REF. ROUND: ALL ASSEMBLIES, MEASURING ETC BY GAUGE SECTION

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SERIAL NO. OF ROUND	EXPECTED PRESSURE /SQ. IN	MEDIUM CALIBER GAUGE NO.	MEAN OF GAUGES WITH 0.0005" .0010" COPPER WAX PISTON CL PISTON CL OBT CUPS OBTRACED	MEAN OF ALL VALUES IN ROUND	INDIV PRESSURE FIXED	MAX DISPERSION GAUGES VALUES 0.0005" 0.0010" COPPER WAX PISTON CL PISTON CL OBT CUPS OBTRACED	INDIVIDUAL DISPERSION WITH OF FIRING	JATE									
1	ROUND	*1501N 4075" MICR SPINDLE)	0.0005" .0010" COPPER WAX PISTON CL PISTON CL OBT CUPS OBTRACED	16.340	+ 560 + 760 - 1440 + 110	-100 +100 -775 +775	-100 +225 -1000										
2	69	16,500	5942 16,900 4525 17,100 (2* 140) 4734 14,900 4190 16,450	{ 17,000 { 16,875 { 15,900	+ 560 + 760 - 1440 + 110	2200 2200 2200 2200	+100 +100 +225 -1000										
3																	
4																	
5																	
6	70	PWD POWDER	4970 17,950 2422 17,850 4748 13,700 2834 13,450	{ 17,900 { 15,825 { 15,825 { 15,740	+ 2,210 + 2,110 - 2,040 - 2,290	4,500 4,500 4,500 4,500	+50 -50 +2025 -2,125	+2,125									
7																	
8																	
9																	
10	71		5908 17,575 3640 17,500 4744 16,875 4329 14,600	{ 17,540 { 17,225 { 15,740 { 15,740	+ 935 + 860 + 235 - 2,040	2975 2975 2975 2975	+35 -35 +215 -350	+350									
11																	
12																	
13																	
14	72		4774 16,150 1728 16,200 4875 14,200 3259 14,925	{ 16,175 { 13,615 { 13,615 { 13,070	+ 1,550 + 1,580 - 3,420 + 305	5,000 5,000 5,000 5,000	-25 +25 -25 +1,250	+2,475									
15																	
16																	
17																	
18	75	16,500	5942 17,300 4825 17,150 4734 14,800 4190 15,950	{ 17,225 { 16,050 { 15,375 { 15,375	+ 1000 + 850 - 1,500 - 350	2,350 2,350 2,350 2,350	+75 -75 +1,100 -1,100	+1,250									
19																	
20																	
21																	
22	76		4970 18,700 2422 18,475 4748 14,850 2834 10,950	{ 18,590 { 14,715 { 14,715 { 12,900	+ 2,955 + 2,750 - 1,895 - 4,915	7,750 7,750 7,750 7,750	+110 -110 +3,765 -3,765	+1,925									
23																	
24																	
25																	
26	77		5908 18,000 3640 17,350 4744 17,150 4329 15,250	{ 17,675 { 16,300 { 16,200 { 15,745	+ 1,060 + 410 + 210 - 1,690	2,750 2,750 2,750 2,750	+325 -325 +1,050 -1,050	+425									
27																	
28																	
29																	
30	78		4774 17,025 1728 16,700 4875 17,850 3259 14,325	{ 16,870 { 16,515 { 14,940 { 14,590	+ 1,300 + 975 - 2,875 + 600	4,175 4,175 4,175 4,175	+170 -170 +185 -185	+2,090									
31																	
32																	
33																	
34																	
35																	
					16,050	14,640	17,370	16,000	16,000	16,000	4,200	3,725	11,40	111	12,35	2,690	

EXHIBIT "F"

REMARKS